Great Lakes Fishery Commission
Lake Michigan Committee Meeting
Ypsilanti, Michigan
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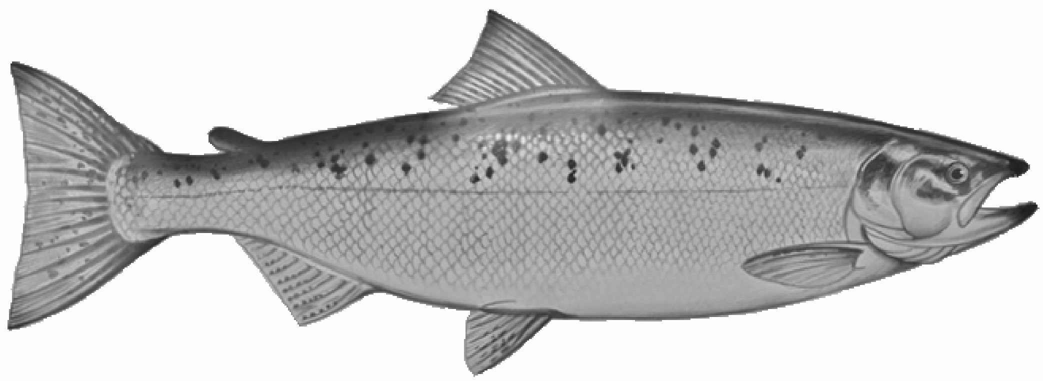

Status of Chinook Salmon in Lake Michigan, 1985-2006

Report from the Salmonid Working Group
to the Lake Michigan Committee

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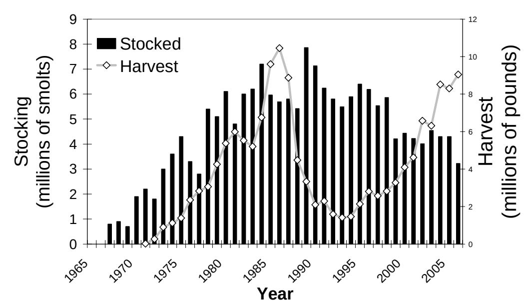
Introduction

Salmonines play an important role in the Lake Michigan ecosystem. In particular, Chinook salmon *Oncorhynchus tshawytscha* were introduced in 1967 to help control exotic forage fishes such as alewife *Alosa pseudoharengus* and rainbow smelt *Osmerus mordax*. Chinook salmon populations now support a valuable fishery and significantly suppress alewife populations. The overall fisheries management goal established for Lake Michigan in the Fish-community Objectives (FCO) is to restore and maintain the biological integrity of the fish community so that production of desirable fish is sustainable and ecologically efficient (Eshenroder et al. 1995). The objective specifies establishment of a diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg, of which 20-25% is lake trout.

Inherent in this objective is the desire to maintain a salmonine community dominated by Chinook salmon (i.e., target annual yield of 3.1 million kg) in sufficient abundance to suppress alewife populations but not beyond levels where predator consumption would threaten food web integrity. The Salmonine and Planktivore Objectives are based on the understanding that large populations of exotic forage fishes, such as alewife and rainbow smelt, negatively impact recruitment of native fishes, and that controlling exotic forage fishes presents an opportunity to create new, diverse fishing opportunities. Therefore, progress toward these objectives is based on an evaluation of the balance between predator and prey (e.g., Chinook salmon and alewife interactions) rather than suppression of alewife through extreme top-down predation.

Stocking levels were highly correlated with harvest in the first two decades of stocking. There was a disparity between stocking and harvest even with sustained stocking rates during the late-1980s. More recently, it is apparent that trends in harvest are no longer related to stocking alone (Figure 1).

Figure 1. Lakewide stocking and harvest



Chinook salmon experienced a noticeable disease epizootic and significant decline in abundance, possibly resulting from an increase in natural mortality brought on by nutritional stress in 1987-88. In 1999, Chinook stocking was reduced in hopes of minimizing risk to the fishery associated with instability in Chinook salmon survival (Figure 1). Through the Lake Michigan Technical Committee process, a Salmonid Working Group (SWG) was established to identify the effects of the stocking reduction and to identify indicators useful in the early detection of Chinook salmon population stress in the future; these indicators were originally referred to as the "10 Red Flags".

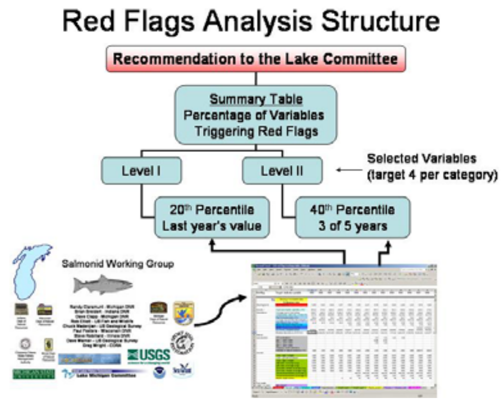
Currently, the SWG role is to continue the development of a science-based approach for annually evaluating measurable indices of the Chinook salmon population and to make recommendations for salmon management based on the Red Flags analysis. Recommendations from the analysis last year, combined with consultation with managers and constituents, resulted in a lakewide stocking reduction by 25% for the 2006 Chinook salmon year class (Figure 1).

Methods

The SWG uses a set of criteria to measure the health of the Chinook salmon population and evaluate potential threats to predator-prey balance. The biological criteria utilize all currently available data from ongoing assessments, including: estimates of **abundance** from creel and fishery-independent surveys, records of stocking and estimates of **natural reproduction**, estimates of size at age and **growth**, trends in **ration and forage fish** abundance, and indices of **fish health**. For each biological category, we have several indices available for analysis. However, we have selected only a few representative parameters from each category to present here. We used the frequency distributions of these variables to indicate when values for the current year (Level I) or three of the previous five years (Level II) are outside an acceptable range.

- **Level I**: A value from the most recent year of data lower than the 20th percentile will trigger a red flag.
- **Level II**: Values during three out of the last five years which are lower than the 40th percentile will trigger a red flag.

If more than 50% of the variables for either level indicate red flags, the SWG will make a recommendation to the Lake Michigan Committee to consider revising management actions (i.e. – stocking rates) for Chinook salmon in Lake Michigan.

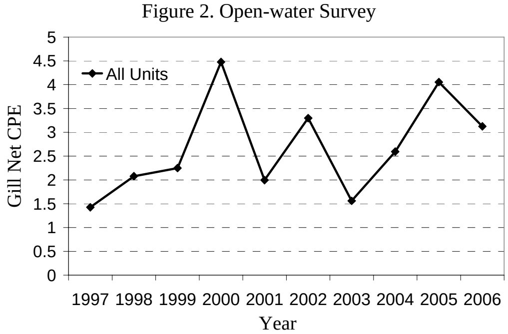


The data included in this report are provided by several agency and university sources. Members of the SWG assist in the collection and/or consolidation of such data by providing summary statistics in a lake-wide time-series table. The data table covers 1985-present; however, there are years with missing values where data were either not collected or are not yet available.

Results and Discussion

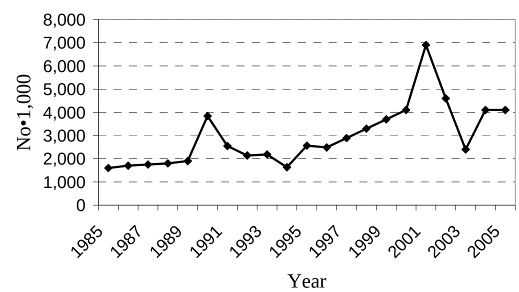
Abundance: Harvest, catch rates, survey CPEs, and periodically estimated standing stock size (catch-at-age analysis) are utilized to evaluate trends in abundance. Lake-wide harvest was highest in the late 1980s, declined substantially during 1989-1994, and has been increasing since 1995 (Figure 1). Annual lake-wide harvest has ranged from 0.6-4.4 million kilograms (kg) with an average (±SE) harvest of 2.16±2.8 million kg (Table 1). Estimated harvest for 2006 was approximately 4.1 million kg. Similarly, catch rates in the recreational fishery declined in the late 1980s, were low during 1992-1994, but have been rising since 1995. Average catch rate over the entire time series is 0.05±0.01 and ranged from 0.01-0.12 fish per hour (Table 1). Catch rates for 2006 were not available for this report, but in 2004 catch rates were extremely high (>0.1 fish per hour) and may be indicative of unusually high densities of Chinook salmon, low prey abundance, or a combination of both. Unlike recreational catch rates, survey CPE increased in 2003 to 2005, but decreased in 2006 (Figure 2). Harvest triggered a level I red flag, and both harvest and survey data triggered level II red flags (Table 1).

Figure 2. Open-water Survey



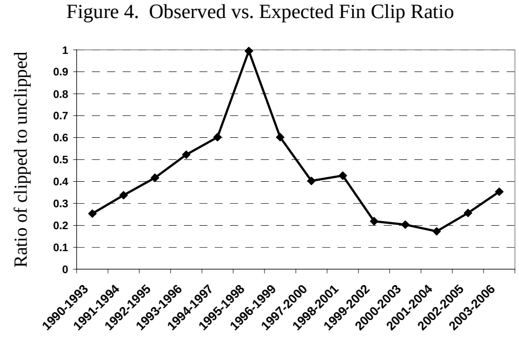
Reproduction: Recruitment of naturally-produced Chinook salmon smolts has increased since their introduction in 1967. Natural reproduction has been estimated periodically throughout the period 1985-2004, and estimates in the early 1990s from oxytetracycline (OTC) studies suggested that natural recruitment accounted for 29-35% of lake-wide adult stocks when stocking levels were near their highest (6-7 million smolts; Figure 3). Estimates for 2001-2003 from OTC-marked fish collected in 2004 by the Michigan Department of Natural Resources indicate that wild fish recruitment has continued to increase and natural recruits may account for 50% of the lake population (Table 1). Based on these studies, we assumed an annual natural recruitment of approximately 50% contribution from wild production (4 million smolts in 2006) for years without empirical estimates.

Figure 3. Natural Reproduction



Because individual stream estimates and lakewide smolt estimates are not available for 2005 or 2006, we substituted (for the red flags analysis) a ratio of the percentage of marked fish (i.e., any fin clip) in the open-water survey to the percentage of marked fish stocked. The proportion of natural recruits in the lake increases as the clip ratio approaches zero (Figure 4). Three year averages were used to reduce variability in the analysis. The clip ratio triggered a level II red flag, suggesting that natural recruitment in recent years has been relatively high (Table 1).

Figure 4. Observed vs. Expected Fin Clip Ratio



Growth: Several weight at age indices suggest that growth conditions have changed over time, presumably from changes in Chinook salmon abundance, forage levels, and environmental factors (Figures 5 and 6).

Figure 5. Weight-at-age 2

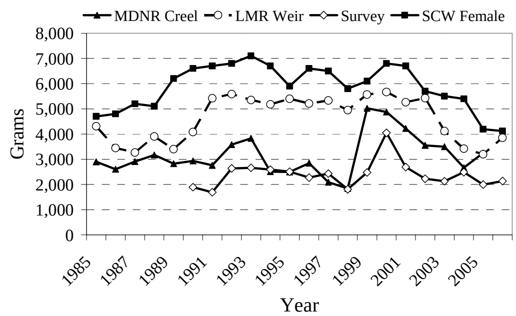
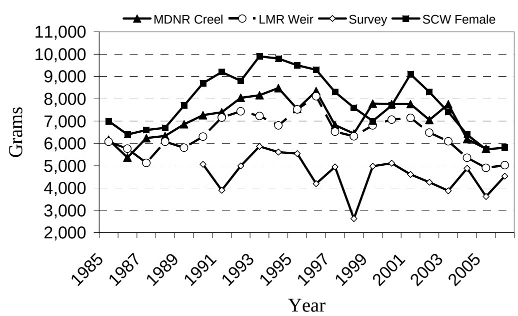
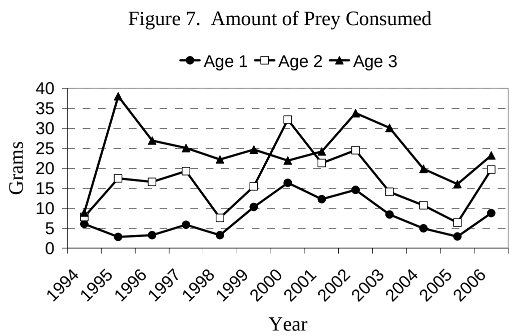


Figure 6. Weight-at-age 3

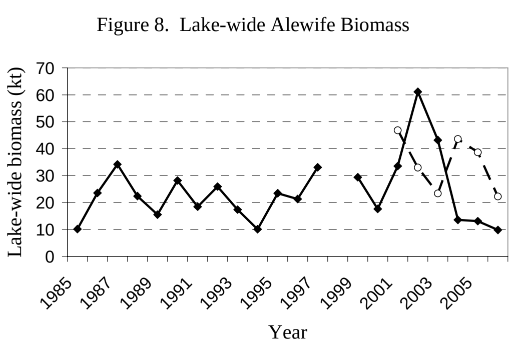


We have selected weight at age-2 from the open-water survey (male and female combined), weight at age-3 (female) Chinook salmon from Strawberry Creek (WI) weir returns, and weight at age-3 from the recreational fishery to assess changes in growth (Table 1). Also, we use a standard weight index from Strawberry Creek weir to track changes in growth conditions. Chinook salmon were sampled during June and July in the open-water survey; weir return data were collected in September. Recreational fishery data for 2006, however, were not available at the time of this report. We chose these sources of growth data because they are collected over a relatively short time period, collected during two different seasons, and the large sample sizes reduce variability in size-at-age estimates. Most of the data sources indicate that weight at age peaked in 2000-2001, following the production of an abundant year class of alewife in 1998. Average weight at age-2 from the open-water survey was 2,371±108 grams (g) and ranged from 1,690-4,049 g throughout the time series (Figure 5). Age-2 fish in 2006 were 2,136 g which was slightly larger than 2005, but smaller than average (Table 1). Weight of age-3 Chinook salmon at the Strawberry Creek weir and the standard weight index in 2006 also increased slightly from 2005 where they were the lowest of the time series. The modest increase suggests that growth conditions during 2005-2006 improved (Table 1). With the exception of the survey, growth indices did not improve enough in 2006 as weir and standard weights were flagged for level I and II.

Ration and forage: Trends for the index of ration (grams of prey in stomach) also suggest that food availability for Chinook salmon has declined in recent years, but improved slightly in 2006. For most age classes of Chinook salmon, ration was low in 1998, increased for several years following the strong 1998 year class of alewife, declined substantially from 2002-2005, and increased in 2006 (Figure 7). Average ration for 1990-2006 was 15.6±1.6 g and 24.2±1.9 g for age 2 and 3 Chinook salmon, respectively (Table 1). In 2006, ration was above average at 19.6 g for age-2 and below average at 23.2 g for 3 year olds. Both indices improved and did not trigger level I or level II red flags.



Estimates of forage fish biomass are reported in kilotons (kt) of age-1 and older alewife from bottom trawl surveys and in kt of total alewife biomass from acoustic surveys (Figure 8). Average biomass from bottom trawl surveys is 23.5±2.3, ranging from 9.8-61.1 kt during 1985-2006 (Table 1). The alewife biomass in 2006 (9.8 kt) was the lowest value in the time series. Therefore, a red flag was triggered for level I and level II bottom trawl data. Alewife biomass from acoustic surveys averaged 34.6±4.2 kt, ranging from 22.3-46.9 kt from 2001-2006. Alewife biomass estimated from acoustic surveys decreased in 2006 (22.3 kt), remained below average, and triggered a level I red flag.



The 1998 year class of alewife constituted the majority of adult alewife biomass during 1999-2004, and the depletion of that year class by predation and natural mortality likely accounts for the drop in biomass observed in the bottom trawl survey. In 2005, the acoustic estimate suggested that young-of-year production was higher than in recent years (2001-2004). It appears that the 2005 year class was strong and likely influenced the increases in growth and ration of Chinook salmon during 2006, but also the 2005 alewife year class likely experienced high predation mortality as indicated by the continued decline in total alewife biomass.

Fish health: Fish health has been monitored using several tests (e.g. visual signs, FELISA, QELISA, DFAT) for the presence of *Renibacterium salmoninarum*, the causative agent for bacterial kidney disease (BKD). Stress mediated diseases such as BKD can have strong regulatory influences on Chinook salmon populations. Using consistent methods, gross clinical (visual) signs of disease have been recorded for fish captured in the open-water survey and weir returns. On average, about 94.8±0.65 % and 88.4±3.9 % of fish show no visual signs of disease in open-water surveys and weirs, respectively (Table 1). Visual signs of Chinook salmon showing signs of disease from both data sources have declined through time and currently are at an all time low, with less than 4% of fish showing visual signs of disease (Figures 9 and 10).

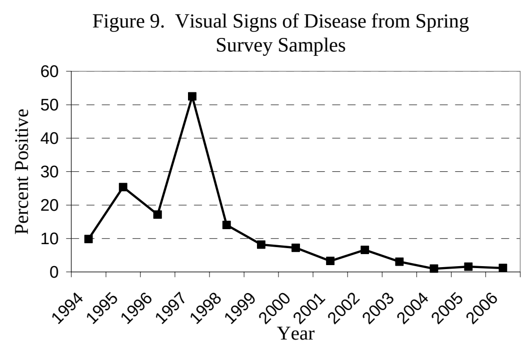
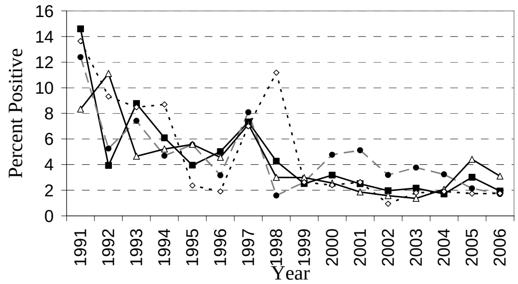
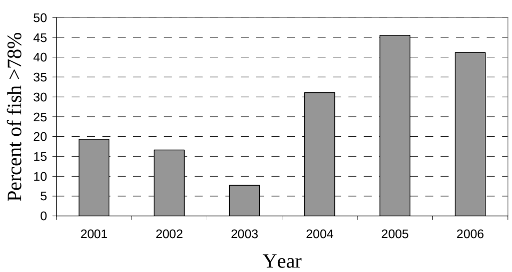


Figure 10. Visual Signs of Disease from Weir Returns



Percent water in the body muscle can be used to evaluate changes in fat reserves. Laboratory and field studies have been used to establish a level of 78% water in the muscle as an indicator of insufficient fat reserves. Percent water results from 2001-2006 suggest that Chinook salmon in Lake Michigan may have entered into a period with very low energy reserves (Figure 11). A level I indicator was triggered for percent water in 2006.

Figure 11. Percent of Chinook salmon above 78% water (high water = low fat)



Summary

Changes in management strategies by adjusting Chinook salmon stocking rates (e.g., 1999 and 2006) have been made through a cooperative process in an attempt to minimize the risk of a lakewide population crash and its effects on the fishery. Stocking reductions are based on a review of biological indicators from the SWG and reflect the consensus of managers from each agency involved in stocking. In addition to the recently established percent water index, the SWG is committed to including new indicators and continuing the ongoing collection and consolidation of lake-wide time series data on salmonines in Lake Michigan.

Chinook salmon harvest in 2004-2006 was above the established reference level set forth in the Salmonine Objective for Lake Michigan (3.1 million kg [6.8 million pounds]; Figure 1). Our analysis of the Red Flag parameters, however, suggests that this harvest level is likely not sustainable. Frequency distributions of the selected parameters indicated that 38.5% (5 of 13) triggered Level I red flags. For Level II, 46.2% (6 of 13) of the parameters indicated red flags. Many of the variables (e.g., growth, ration, forage abundance) have been trending downward, but improved slightly in 2006, likely from alewife production in 2005. However, a number of the 2006 estimates were still well below long-term averages.

As predicted from the 2005 Red Flag analysis, Chinook salmon growth and ration indices increased in 2006. However, total alewife biomass continued to decline likely from increased predation pressure resulting from very high Chinook salmon population levels. Lakewide Chinook salmon stocking was reduced in the spring of 2006 by 25%. The effect of the 2006 stocking reduction should have a latent impact and may not be evident until collection and analysis of the 2007 data. The reduction in stocking along with and the predicted decline in abundance as indicated by the 2006 survey catch rates may help to stabilize predator – prey levels in Lake Michigan.

Our evaluation suggests that we are likely meeting the Salmonine Objective of the FCOs by maintaining predators in Lake Michigan at levels abundant enough to suppress alewife populations. Recent declines in forage fish abundance and Chinook salmon growth have not resulted in disease-mediated increases in Chinook salmon mortality. The FCOs, however, do not define what levels of predator consumption would threaten the integrity of the food web. The Red Flag analysis can be used to evaluate balance between predator and prey and may be useful to redefine fish community objectives in the future.

Recommendations

As stated in *The State of Lake Michigan in 2000* and *2005* reports, stocking levels and harvest expectations for all salmonines should be reviewed and revised (if appropriate) at 5-yr intervals. Unlike during 2000, planktivore populations do not appear to be balanced with predator demand in 2006. If balancing predator demand with planktivore production is a top priority for fishery managers, then implementing a management change to reduce stocking in 2006 was justified.

The *Red Flag* analysis of 2006 data shows increases in growth and ration, which was likely influenced by the increase in prey supply from the 2005 alewife year-class. Therefore, based on the Level I (short term) and Level II (trend) indicators, no changes in management strategies are recommended because less than 50% of the indicators were triggered. The results suggest that either the 2006 stocking reduction was sufficient in reducing Chinook salmon abundance, or the 2005 alewife year class increased prey supply, or a combination of the two factors. It is also possible that implications of the 2006 stocking reduction have are not fully impacted predator-prey levels yet. If these indicators levels are more important to managers, then stocking strategies should be re-evaluated in the future based on more specific management objectives such as: 1) effects of long-term imbalances between forage supply and predator demand, 2) continued need to suppress exotic forage fishes, 3) potential for fishery yield based on variable forage production, and 4) development of specific management objectives for Chinook salmon relative to management of other salmonines in Lake Michigan.

Future Direction

The measure of naturally-produced salmon has been identified as a key uncertainty in the management of Lake Michigan salmonines, especially for Chinook salmon. Starting with the 2006 year-class, all Chinook salmon stocked in Lake Michigan will be marked, the majority using oxytetracycline (OTC). Marking of all Chinook salmon stocked into Lake Michigan will continue through the 2010 year-class. In response to a formal charge from the Lake Michigan Committee (LMC) given to the SWG on March 30, 2006, a monitoring plan, the level of involvement and commitment necessary by each agency, and the methods that will be used to provide reliable estimates of natural reproduction are detailed in a SWG plan (Estimating Wild Portion of Chinook Salmon *Oncorhynchus tshawytscha* from Oxytetracycline Marking) that will start in 2007.

Table 1. Selected red flag variables; data in the summary table was collected during the period 1985-2006.

Biological Variable	Min	Max	Mean	SE	2006 Values	Current Year Level I <20%	Current Year Level I Red Flag	Three Out of Five Years Level II <40%	Three Out of Five Years Level II Red Flag
Abundance									
Harvest (millions of kg)	0.64	4.40	2.16	2.82	4.10	<0.96 or >3.80	**Yes**	<1.31 or >2.05	**Yes**
Catch Rate (n per hr)	0.01	0.12	0.05	0.01	NA	<0.02 or >0.06	NA	<0.04 or >0.05	NA
Survey (gill net CPE)	1.4	4.5	2.6	0.3	3.1	<1.6 or >3.3	*No	<2.1 or >2.6	**Yes**
SCAA Estimate (millions of fish)	7.20	13.66	10.53	4.24	NA	<8.75 or >12.66	NA	<9.87 or >11.01	NA
Natural Reproduction									
Percent unmarked (OTC)	0.23	0.5	0.37	0.05	NA	<0.22 or >0.52	NA	<0.26 or >0.48	NA
Clip ratio (Obs. Vs. Exp.)	0.17	1.00	0.42	0.05	0.35	<0.25 or >0.60	No	<0.34 or >0.42	**Yes**
Stream Production (n per stream)	5,400	389,317	142,504	24,430	NA	<28297 or >280000	NA	<85000 or >119000	NA
Total Recruitment (n x 1 million)	6.9	11.1	8.4	0.2	8.3	<7.5 or >9.1	NA	<7.9 or >8.5	NA
Growth Indices									
Survey weight-at-age 2 (g)	1,692	4,049	2,371	108	2,136	<1,894 or >2,647	No	2,230 – 2,504	*No
SC Weir weight-at-age 3 (g)	5,730	9,900	7,679	241	5,810	<6,520 or >9,140	**Yes**	7,000 – 7,700	**Yes**
Creel weight-at-age 3 (g)	5,367	8,479	7,241	195	NA	<6,334	NA	<7,050	NA
Standard weight (g)	3,814	4,585	4,265	35.1	3,920	<4,131 or >4,404	**Yes**	4,222 – 4,313	**Yes**
Ration and Forage Abundance									
Ration age 2 (g)	6.4	32.1	15.6	1.6	19.6	< 7.7	*No	<14.3	No
Ration age 3 (g)	8.9	38	24.2	1.9	23.2	<19.1	*No	<22.8	No
Bottom trawl (kt)	9.8	61.1	23.5	2.3	9.8	<13.3	**Yes**	<18.3	**Yes**
Acoustic biomass (kt)	22.3	46.9	34.6	4.2	22.3	<22.7	***Yes**	<31.1	***Yes**
Fish Health									
Visual Signs – Survey (% w/o)	87.6	98.4	94.8	0.65	98.0	<81.2	No	<91.2	No
Visual Signs - Weir (%w/o)	47.5	99.0	88.4	3.9	98.4	<92.6	No	<94.8	No
Percent Water Index (>78%)	7.7	45.5	26.9	6.1	41.1	>43.7	**Yes**	>33.1	No
Weir DFAT: Strawberry Creek	0	67	10.8	3.7	0	>15.0	NA	>6.8	NA

* = A change in the Red Flag from the last assessment. NA = data not available.